IMAGE RESOLUTION: ITS SIGNIFICANCE IN A WILDLAND AREA

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INTRODUCTION

An experiment has been carried out to determine the information content of simulated space photos as a function of various levels of image resolution. The study was performed using a series of images taken of the San Pablo Reservoir Test Site (NASA Test Site #48), each purposely degraded optically to a different level of ground resolvable distance (GRD). This research seeks to answer two questions. First, given low resolution ERTS data within the next few years, how well can a skilled image analyst identify the major vegetation-terrain types found to occur within the chaparral-hardwood-grassland cover type of California? Second, if certain vegetation/terrain types cannot be consistently identified on simulated low resolution imagery, what level of image resolution is required that would allow a skilled interpreter to discriminate between various types?

Until the recent series of Gemini and Apollo photographic experiments, remote sensing research regarding application of spaceborne imagery to earth science problems was based mainly on an analysis of airborne imagery. These studies, combined with conjectured reasoning, have led to a wide variety of opinions as to the usefulness of satellite imagery. Fortunately, the recently procured space photos are providing authentic data from which definitive experimental results can be derived. Experiments to date, however, suffer from two limitations: (1) existing and available spaceborne imagery as obtained by the Mercury, Gemini and Apollo astronauts give coverage only of the lower latitudes of the United States -- due to the constraints of the orbital path -- thereby limiting the kinds of resource phenomena that might be studied, and (2) each study, to our knowledge, has simply sought to determine what kinds of useful information might be extracted from space photos with only minimal consideration to the informational requirements of users. The work reported herein not only applies to a resource inventory problem indigenous to the mid-latitude western United States but also approaches the resource inventory problem from a user's standpoint, i.e., given a particular problem, what kinds of spaceborne imagery (in this case, what level of resolution) is required so that useful information can be extracted from the imagery.

SIMULATED SPACE PHOTOGRAPHS

Probably the most common method of simulating synoptic view space photography is to prepare an uncontrolled photo mosaic from conventional vertical aerial photos of a large area and then reproduce the mosaic on a single sheet of film. Low resolution is obtained by greatly reducing photographic scale. Photographic tone, however, is disrupted throughout the final image due to haloing and fall-off common to each photo within the mosaic. This causes tonal mismatches in the mosaic that are easily confused with tonal differences between resource features. Since image tone or color, as opposed to image detail or stereo parallax, is the primary criterion used by the image analyst when interpreting low resolution space photos, a photo mosaic reduced in scale does not provide a realistic simulation of a space photo. Another method that is sometimes used is to enlarge or reduce the photo, as desired, with a projector that is purposely "out of focus" to the extent necessary to produce the desired image degradation. The problem which arises from this method is that linear features such as roads or boundaries between different vegetation types, because they are out of focus, become displaced or spread out and if defocused enough will become double images taking up a greater areal extent on the resultant degraded image than they do on the original. To overcome such problems a technique has been developed for degrading aerial photography in such a way that image sharpness can be manipulated while image color or tone remains nearly unaltered. The technique entails reproducing an original high-altitude, small scale photograph with a flat diffusing plate of frosted acetate placed at various positions between the original photo and the copy camera (see Figure 1). In this manner, natural terrain features up to several hundred feet in size can be made to disappear or reappear on the copy photograph depending upon the distance between the acetate plate and the original photo. The scale of the copy photo is a function of copy camera focal length and distance from the copy camera lens to the original photo.

In this case, a single Ekta Aero Infrared photograph taken of the San Pablo Reservoir Test Site from an altitude of 15,000 feet above terrain by the NASA Convair 240 on June 1, 1968 was chosen for detailed analysis. More than 50 photo reproductions were made of this image, each time slightly changing the position of the diffusing screen thereby spanning the range of GRD from a few feet, as seen on the original photo, to several hundred feet on the most degraded image. Objects of known size seen on different backgrounds were examined on each image. In this way a resolution value in terms of ground resolvable distance was assigned to each image. A representative value was assigned to both high contrast features (e.g., dark toned tree crowns on a light toned grass background) and to low contrast features (e.g., dark toned tree crowns on a dark toned brush background). For testing purposes, five images ultimately were selected, each representing a distinct level or range of image resolution which was quite different from all others (see Figures 2, 3, 4, 5 and 6).

INTERPRETATION TESTS

Tests were conducted using these five images to determine their information content in terms of portraying identifiable tonal and/or textural signatures for various terrain and vegetation types (i.e., Monterey pine, Pinus radiata; blue gum eucalyptus, Eucalyptus globulus; mixed hardwoods -- oak, bay, madrone, buckeye chaparral -- coyote brush, poison oak; annual grasslands -- wild oats, soft chess, brome, ryegrass, fescue; water bodies -- reservoirs, lakes, ponds; and non-vegetated areas). Emphasis should be placed on the fact that these tests were oriente towards a single, well-defined user informational problem -- vegetation/terrain mapping. A group of 15 highly skilled photo interpreters was drawn from the pool of personnel working at the Forestry Remote Sensing Laboratory. These individuals were divided into five groups of three interpreters per group and each group analyzed a single image on which 100 randomly chosen points of known identit were to be identified. Consequently, three sets of data were generated for each image yet each interpreter analyzed only one image.

Prior to analyzing each of the test images the photo interpreters were trained in such a way as not to bias the test results. A photo interpretation key plus accompanying aids were carefully prepared in which the identifying characteristics of each vegetation/terrain type were presented in (1) a summary table, (2) a dichotomous word description and (3) selective photo illustrations. The several photo examples appearing in the key were selected from an adjacent but analogous area and enough examples were made of each type showing the range in tone or color variability exhibited by each type.

INTERPRETATION TEST RESULTS

Interpretation results for the various images appear in tables below the corresponding images in Figures 2 through 6. These tables show the cumulative results of the three interpreters (data along rows for each type) along with the actual ground truth (data down the columns). For example, consider the case of chaparral in Figure 2. First reading down the column marked (C), out of a total of 48 plots known to be chaparral, 41 were correctly identified, however, 5 were called mixed hardwoods and 2 non-vegetated, resulting in an omission error equal to 7. Reading across the row marked (C), out of a total of 59 plots called chaparral by the interpreter, 41 were correctly identified, however, 7 mixed hardwoods plots, 8 grassland plots and 2 non-vegetated plots were incorrectly identified as chaparral, resulting in a commission error equal to 18. Hence, of 48 chaparral plots, 41 were correctly identified yielding a percent correct rating of 86%. Percent commission error for chaparral is computed by dividing the number of chaparral commission errors made by the interpreter, 18, by the total number of plots called chaparral, 59; i.e., 33%. Interpretation results, expressed in percent, are presented in tabular form in Figures 8 and 11 and graphically in Figures 9, 10, 12 and 13.

DISCUSSION OF TEST RESULTS

The results presented here indicate that although there is definite decrease in interpretability as ground resolvable distance increases, some valuable information can be gained by using even the poorest photography. The greatest decrease in interpretability between two adjacent photographs (with respect to resolution) was between Image 1 and Image 2. On the best photography, Image 1 (5-10 ft. GRD), 90.3% of all plots were correctly identified whereas on Image 2 (50-100 ft. GRD) only 70.0% were correctly identified. This decrease seems to be due to an almost complete loss of shape, shadow, and textural differences on Image 2 which <u>were</u> present on Image 1. Due to color similarities, shape and textural differences are very important for the identification of Monterey pine (MP), eucalyptus (E), mixed hardwood (MH), and chaparral (C); MP and E both appear dark red in color and MH and C both appear bright red. It is interesting to note here that in a somewhat similar study conducted last year in the Phoenix area, it was concluded that no improvement was made in the identification of agricultural crops on high altitude aerial photography (5-10 ft. GRD) versus Apollo 9 photography (200-300 ft. GRD). In that study, however, large homogeneous fields exhibiting unique tone signatures were interpreted, and those signatures, seen on both types of photography, were not significantly influenced by size, shape, shadow and texture characteristics of individual plants. Such identifying characteristics are useful only on extremely high resolution imagery, exhibiting a GRD of less than two feet.

The poorer results from the interpretation of Image 2 can be attributed for the most part to both omission and commission errors within the four above vegetation types. With the exception of MP, the percent correct for each of these four vegetation types decreased by amounts ranging from 28.6% for MH to 43.8% for C. The decrease in percent correct for MP was only 7.4% but the increase in percent commission for MP was 42.5% (from 3.6% to 49.0%) and for the remaining three types the increases in commission errors were as follows: MH - 22.3%, C - 31.8%, and E - 0.0% (no commission errors for E). As can be seen by the above figures (from Figure 8), the loss of shape and texture as identifying characteristics affected the interpreters' ability to correctly identify MP, E, MH, and C. The absolute values corresponding to the above mentioned omission and commission errors can be seen in Figures 2 to 6.

The interpretation results also are given in Figure 8 for the remaining vegetation and terrain types: annual grassland (G), water bodies (W), and non-vegetated areas (N). The interpretability of these types was not as affected by loss of textural evidence as that of MP, E, MH, and C. The percent correct and percent commission errors for these categories were not found to be significantly different for Images 1 and 2 at a .05 significance level. On the other hand, for both MH and C there was a significant difference for the percent correct between Images 1 and 2 at a .05 significance level and also a significant difference in commission errors between the images for MP, MH and C at a .05 significance level. (A one sided t-test was used on the absolute values found in Figures 2 to 6.) Any assumptions based on the figures relating to eucalyptus probably have little significance because the sample size was quite small. The great variation for eucalyptus can be seen by the figures in Figure 8.

The above trends, i.e., the importance of shape and texture for the correct identification of broadleaf or coniferous vegetation types (MP, E, MH and C) and the relative unimportance of shape and texture for the identification of G, W and N are also shown in the graphs in Figure 9 and 10. In Figure 9 the steep drop in percent correct for E, MH and C can be seen whereas there is relatively little drop for G, W and N from Image 1 to Image 2. Figure 10 shows the very steep rise of commission errors for MP, MH and C and the relatively gradual rise of G, W and N.

Apart from the initial drop-off in percent correct between the first two images, the relative drop-off for percent correct for the next three images is more gradual. This gradual decrease in interpretability is to be expected, expecially when trying to identify different types of woody vegetation. As resolution becomes worse the interpreter must rely almost entirely on color which makes differentiations such as that between mixed hardwood and chaparral, both which have a bright red tone, very difficult. In fact, these two vegetation types were the hardest to identify as soon as the images became more degraded. This is evidenced in Figure 8 where using Image 5 (300-500 ft. GRD) the interpreters were only able to correctly identify 21.4% of the MH plots and 29.2% of the C Plots. Monterey pine (MP) was also hard to identify with only 33.3% of the plots being correctly identified.

The annual grassland (G), the water bodies (W) and the non-vegetated areas (N) were more easily identified. The percent correct for W, 83.3%, would have even been higher if the small one-acre pond at point 64 on Image 1, which was resolvable only on Image 1, had been eliminated.

It seems that difficulties are certain to arise when trying to differentiate between woody vegetation types such as MP, E, MH and C on low resolution photography. However, if these are combined into one group, i.e., "woody vegetation", and the interpreter is asked to interpret for woody vegetation, grassland and water bodies, the results might be improved. Figure 11 shows how the results might improve if these categories were used. The graphs in Figures 12 and 13 also show an improvement in results.

The accuracy of identification for the grassland (G) surely would have been much higher if the photography had been flown a month later, July 1 instead of June 1. At the time of the June 1 photography, some of the grassland area still had high reflectance in the reflective infrared portion of the electromagnetic spectrum and shows up pink or red (see point numbers 23 and 90 on Image 1) thus making it easy to confuse it with chaparral which is also pink or red at this time of year.

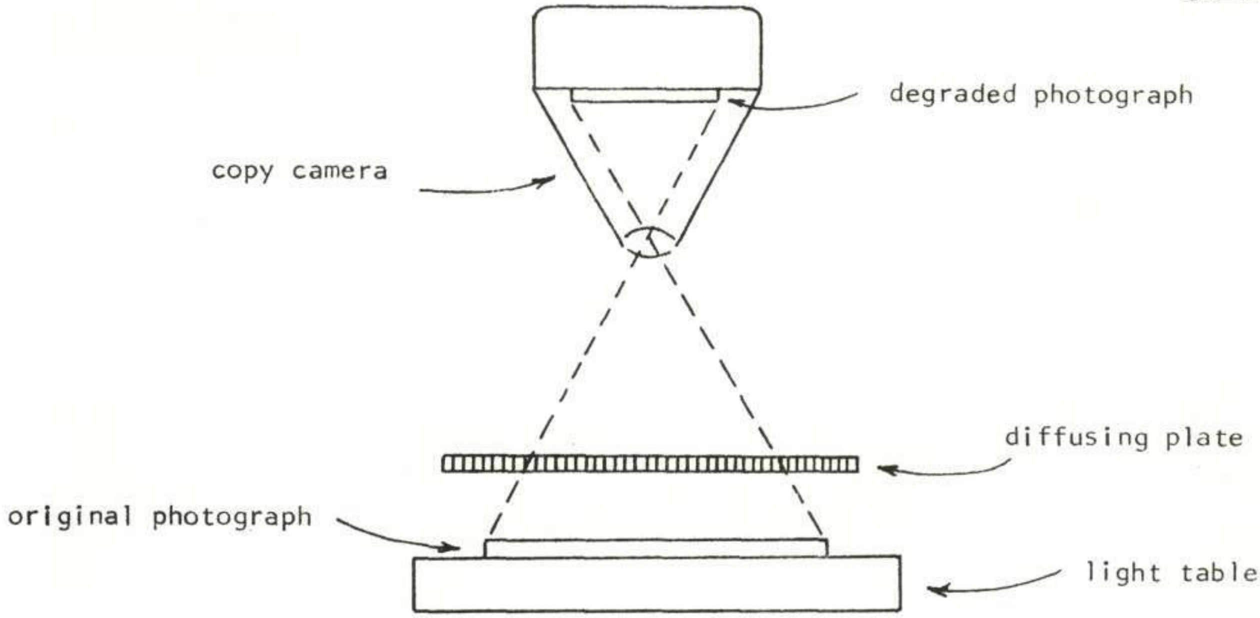
Although interpretability does fall off with increasing ground resolvable distance, very good results were obtained using the photography with the best resolution, and if a more general type of information such as the extent of woody vegetation versus grassland is desired, imagery of the quality obtainable from satellites may be of great utility especially if the optimum dates of photography are flown.

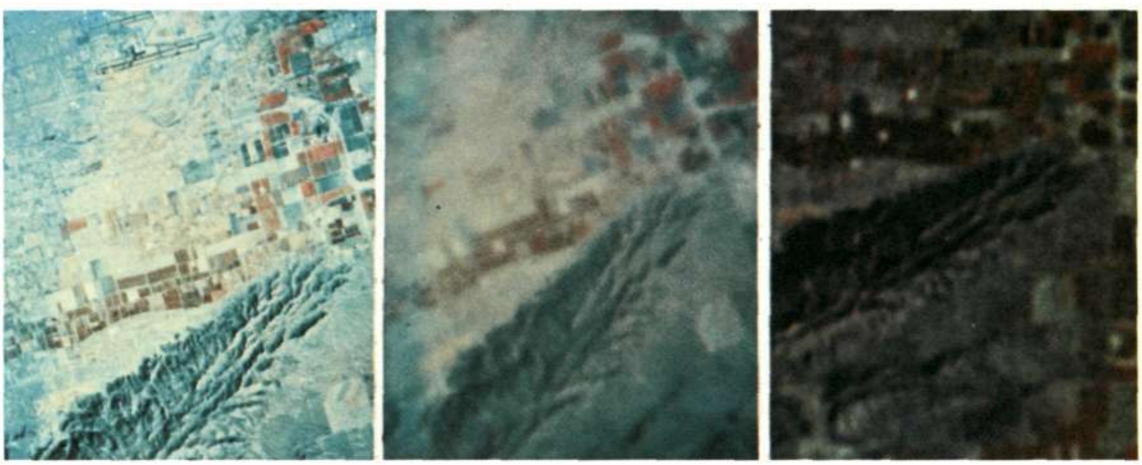
The examples in Figure 14 show a photograph taken on June 1, 1968 and one taken on July 17, 1969. In June the grasslands at "G" are still pink or red and easily confused with the chaparral at "C", but there is little confusion between the same points on the July photograph. There is also a greater contrast between the Monterey pines at "MP" and the mixed hardwoods at "MH" and the chaparral at "C" on the July photograph than there is on the June photograph. Thus by using photographs flown later in the year the results reported on herein could be improved upon considerably.

SUMMARY AND CONCLUSIONS

In summary, the results reported above help answer the two questions stated at the beginning of this paper. First, given (within the next few years) low resolution ERTS data taken of a chaparral-hardwood-grassland type, one could expect that a skilled image analyst could delineate and identify on these images woody vegetation and water bodies with better than 80% accuracy. In addition, annual grassland areas could also be identified with approximately the same accuracy provided the imagery is taken late in the growing season. (It is reasonable to assume that imagery will be available showing natural vegetation in nearly all seasonal states, since the ERTS vehicle will pass over the same point on the earth approximately every eighteen days.) However, the most interesting outcome of this research is in reference to the second question. Note that even if the image resolution capability of the proposed ERTS sensor system was improved from 400 feet GRD to 100 feet GRD, the imagery would remain inadequate for identifying the four primary types of woody vegetation found to occur in this area: Monterey pine, eucalyptus, mixed hardwoods and chaparral. Discrimination between these kinds of vegetative cover is done mainly by recognizing shape, size, texture and shadow characteristics within each type. To include these kinds of information, imagery must have a ground resolvable distance of at least 50 feet. In some instances the user might be satisfied with merely broad categorization; in other instances, however, either he or some other users might require detailed identifications as to individual species. Consequently, only by being able to thoroughly define user requirements can the usefulness of ERTS data, or for that matter, any data be determined. For example in this case, if the user wants to discriminate between woody vegetation, grassland and water bodies, ERTS data exhibiting 400-500 feet GRD will contain a sufficient amount of information allowing such discriminations to be made. However, if the user desires additional information on the various types of woody vegetation, spaceborne data will have to be supplemented with higher resolution (i.e., > 50 ft. GRD) aircraft imagery on which individual tree crowns can be seen.

There is still another respect in which user requirements for information may differ. In some instances the user may need only to know the percentage or total acreage comprised by each vegetation or terrain type throughout the entire area that he seeks to manage. Such information is obtainable, as in the present experiment, merely through type identification at each of a suitably large number of selected spots. For any given type, the amount which it comprises throughout the entire area can then be assumed to be proportionate to its occurence in the dot sample. However, in other instances the user may require a complete "in-place" delineation, showing the exact boundaries of each type, wherever that type may occur within the project area. In order for this second type of requirement to be satisfied, a higher order of image interpretability usually will be required. With respect to both types of problems, spaceborne and airborne data most certainly compliment one another in that an analysis of low resolution synoptic view space photos gives guidance to where and, more importantly, where not to procure supplementary aerial coverage.

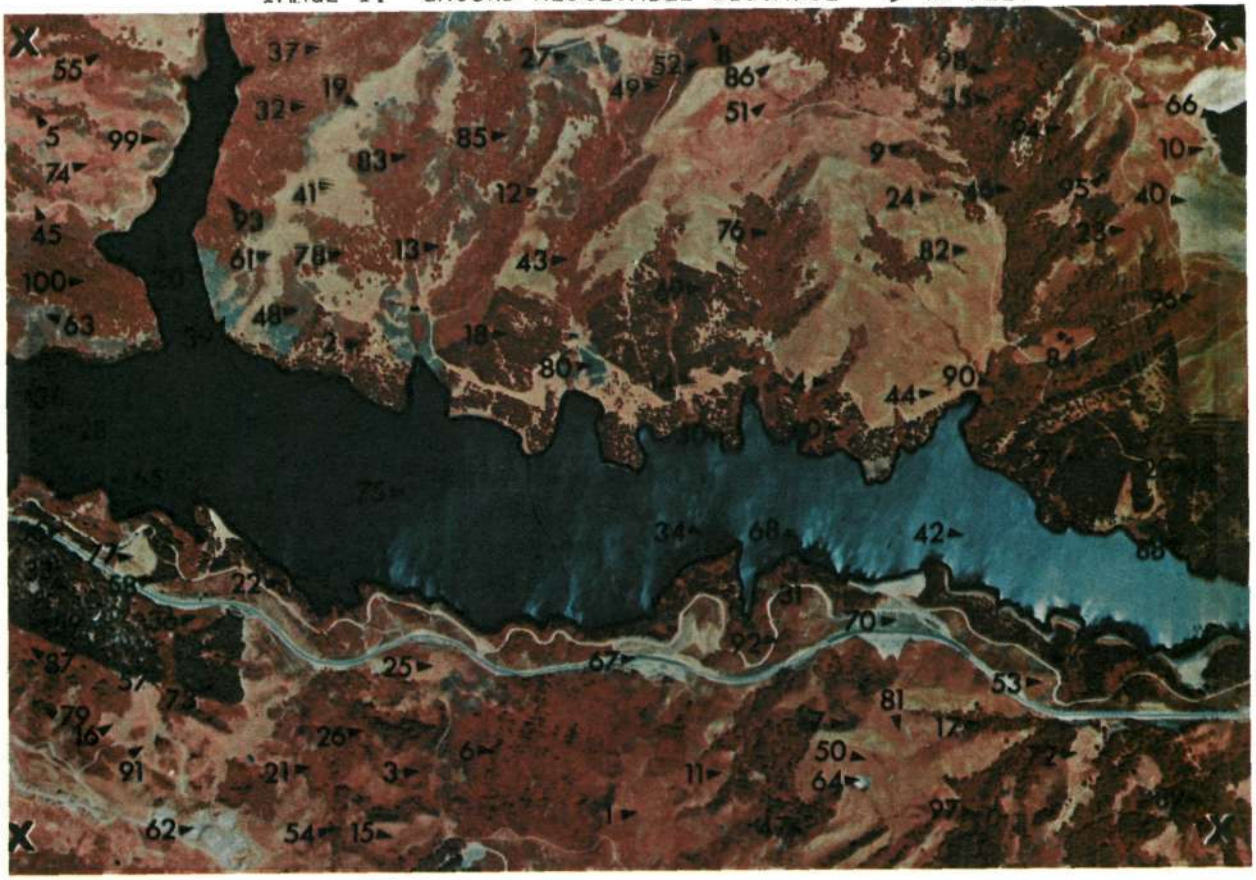




GRD:	10-20'	200-300' (degraded)	200-300'
Scale:	1/300,000	1/300,000	1/300,000
Film Type:	Ekta Aero Infrared	Ekta Aero Infrared	Ekta Aero Infrared
Flight Altitude:	60,000' AMS	60,000'AMS	125 NM
Vehicle:	NASA RB57F	NASA RB57F	Apollo 9
Date:	March 8, 1969	March 8, 1969	March 8, 1969

Figure 1. The three photos shown here are of the multidisciplinary test site at Phoenix, Arizona (NASA Test Site #29). In order to simulate low resolution space photography, high altitude small scale aerial photography was photographed through a diffusing screen made of frosted acetate. By degrading image sharpness without grossly affecting image tone or color, photography can be analyzed that exhibits 200-300 foot GRD, similar to the quality of existing Apollo and Gemini photography. In addition, by shifting the position of the diffusing screen, a photograph can be made with nearly any GRD desirable. (The differences in color balance between the RB57F and Apollo photos are due primarily to the exposure and processing of the original photography and not to the degradation process.)

IMAGE I: GROUND RESOLVABLE DISTANCE = 5-10 FEET



		GROUND TRUTH							TOT. SEEN BY P.I.	COM. ERROR
		MP	E	MH	C	G	W	N		
PHOTO INTERPRETER'S RESULTS	MP	27	1						28	1
	E		11						11	0
	MH			77	5				82	5
	C			7	41	8		3	59	18
	G					67		3	70	3
	W						30		30	0
	N				2			18	20	2
TOTAL PLOTS		27	12	84	48	75	30	24		
OMIS-SION		0	1	7	7	8	0	6		

Figure 2. Three photo interpreters working with the above image produced the cumulative results shown here. A total of 100 randomly distributed points of known identity were used in this interpretation test. The numbers in the body of the array of results indicate the total number of plots identified by all interpreters. The numbers in the bold-faced diagonal row of boxes indicate the number of plots identified correctly.

IMAGE 2: GROUND RESOLVABLE DISTANCE = 50-100 FEET

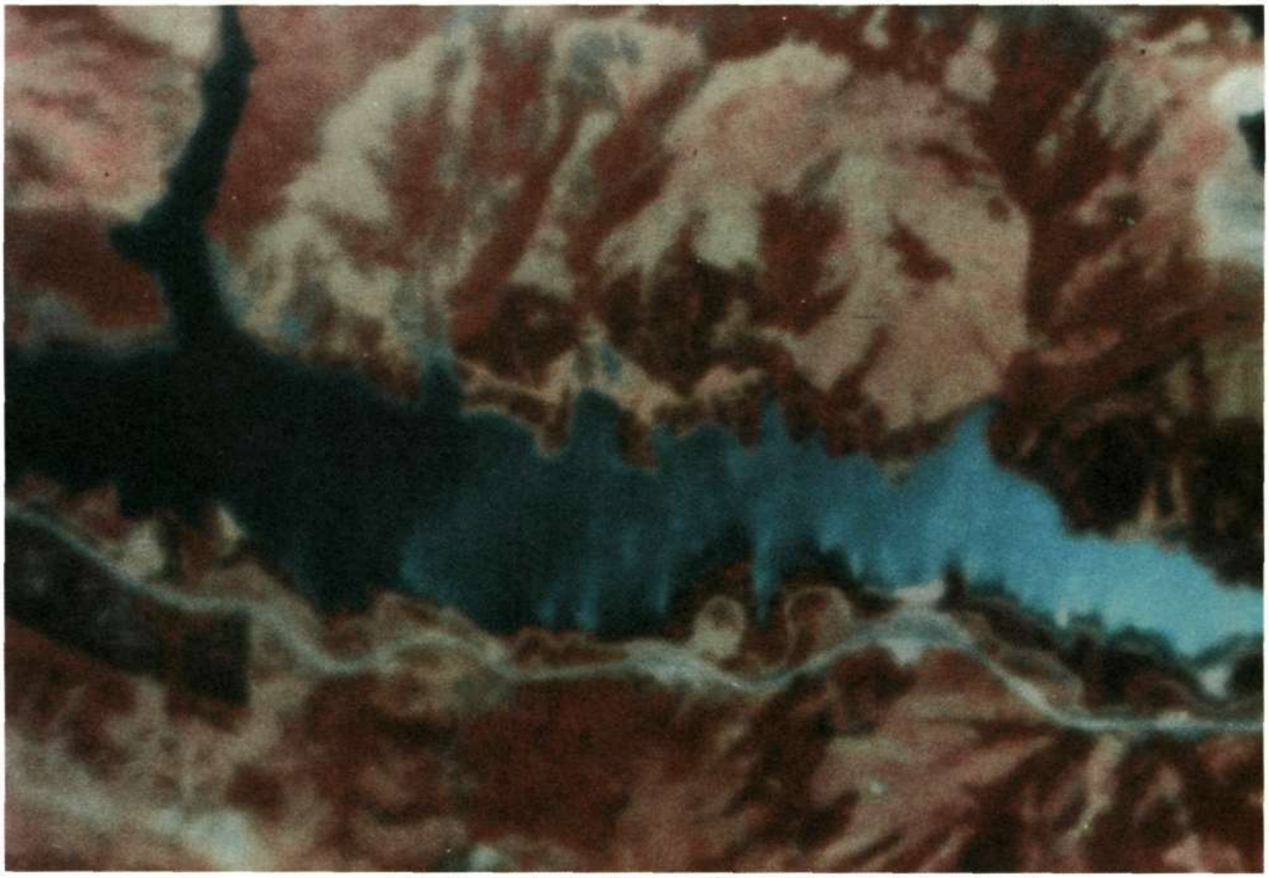


Photo Interpreter's Results	Ground Truth: MP	E	MH	C	G	W	N	TOT. SEEN BY P.I.	COM. ERROR
MP	**25**	5	9	10				49	24
E		**6**						6	0
MH	2		**53**	17	2			74	21
C		1	20	**20**	12			53	33
G			2		**60**		3	65	5
W						**28**	3	31	3
N				1	1	2	**18**	22	4
TOTAL PLOTS	27	12	84	48	75	30	24		
OMIS-SION	2	6	31	28	15	2	6		

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Figure 3. Three photo interpreters working with the above image produced the cumulative results shown here. A total of 100 randomly distributed points of known identity were used in this interpretation test. The numbers in the body of the array of results indicate the total number of plots identified by all interpreters. The numbers in the bold-faced diagonal row of boxes indicate the number of plots identified correctly.

IMAGE 3: GROUND RESOLVABLE DISTANCE = 100-200 FEET

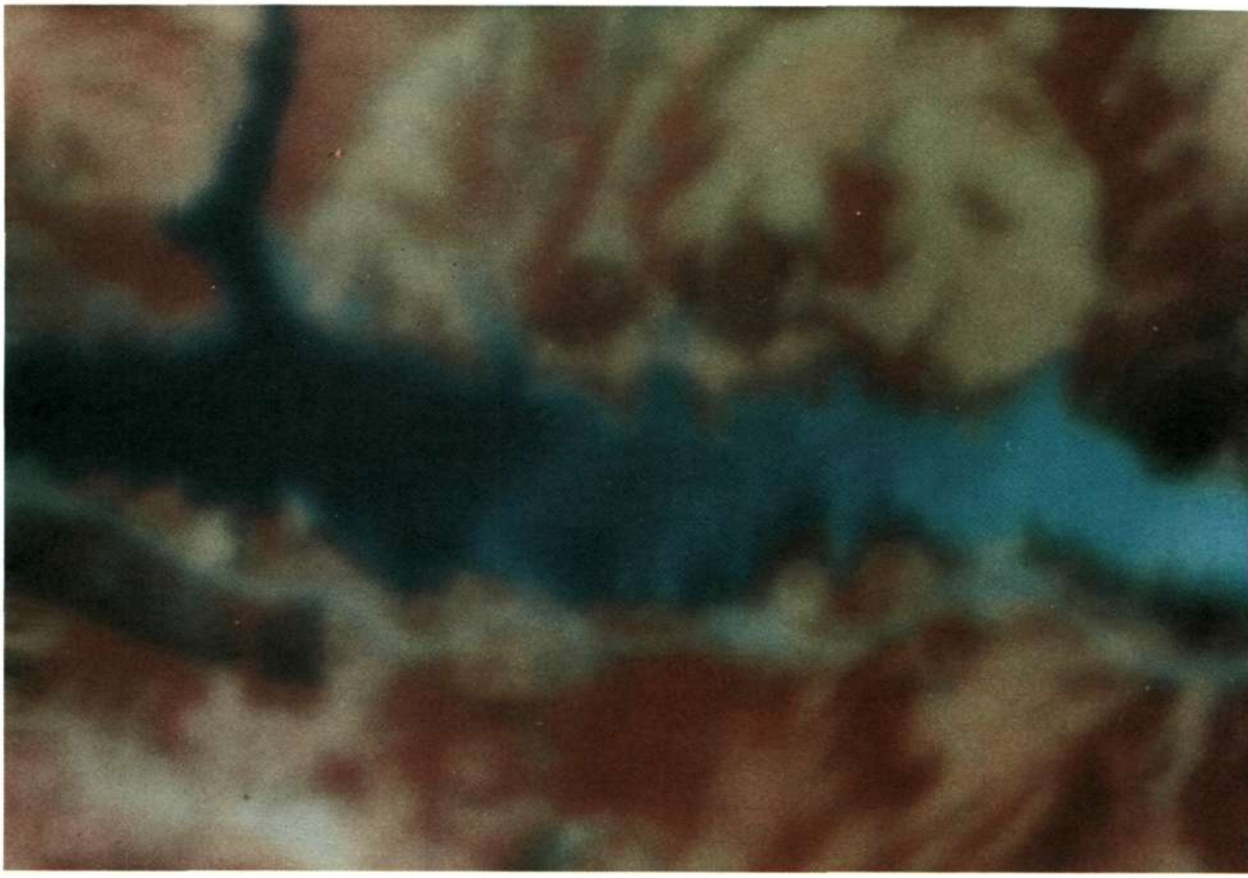

PHOTO INTERPRETER'S RESULTS	GROUND TRUTH: MP	E	MH	C	G	W	N	TOT. SEEN BY P.I.	COM. ERROR
MP	21	1	10	4				36	15
E		9	1	2				12	3
MH	3	1	39	16	3			62	23
C	3	1	27	22	14			67	45
G			4	2	57	3	8	74	17
W					0	27	2	29	2
N			3	2	1		14	20	6
TOTAL PLOTS	27	12	84	48	75	30	24		
OMISSION	6	3	45	26	18	3	10		

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Figure 4. Three photo interpreters working with the above image produced the cumulative results shown here. A total of 100 randomly distributed points of known identity were used in this interpretation test. The numbers in the body of the array of results indicate the total number of plots identified by all interpreters. The numbers in the bold-faced diagonal row of boxes indicate the number of plots identified correctly.

IMAGE 4: GROUND RESOLVABLE DISTANCE = 200-300 FEET

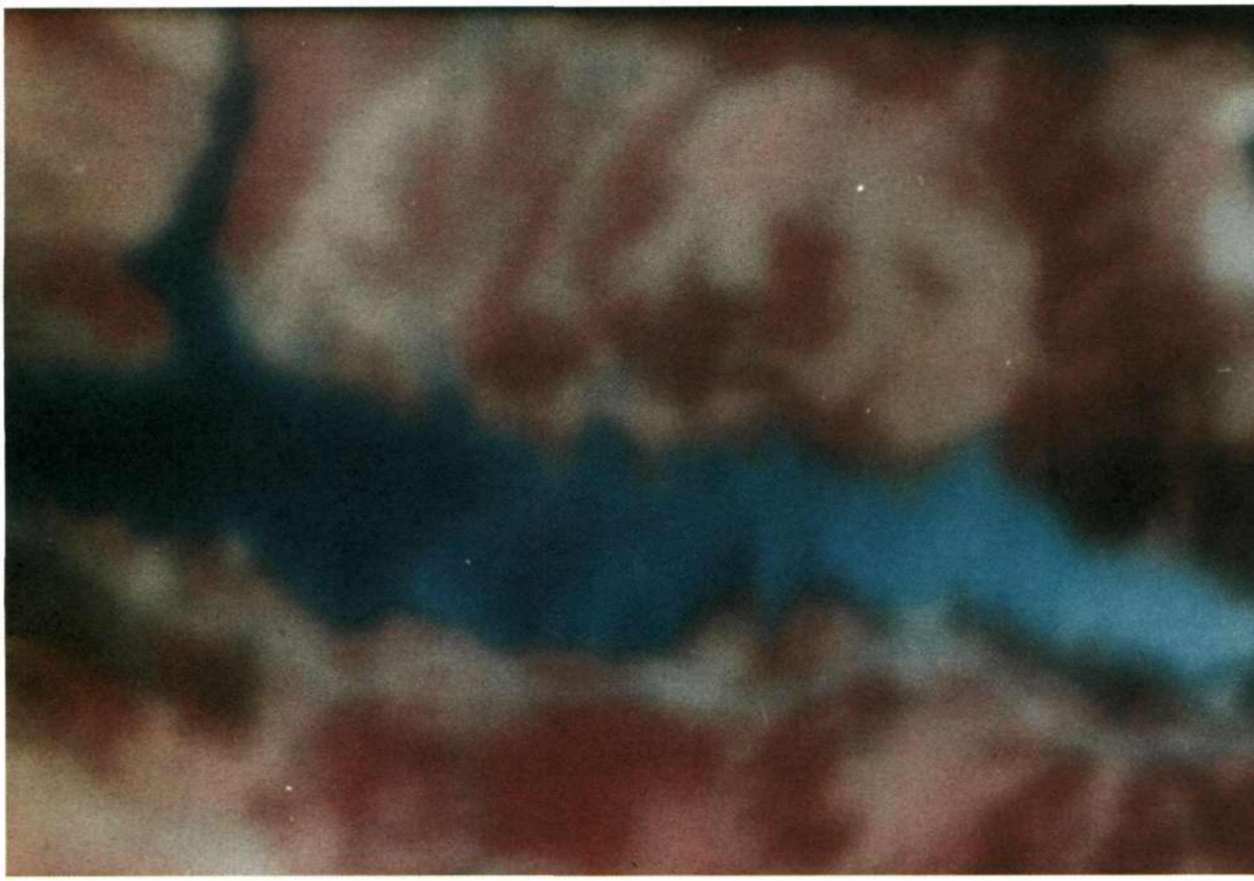

PHOTO INTERPRETER'S RESULTS	GROUND TRUTH: MP	E	MH	C	G	W	N	TOT. SEEN BY P.I.	COM. ERROR
MP	**14**	3	13	7	2			39	25
E	3	**6**	3	4		2		17	10
MH			**22**	11	2			36	13
C	7	2	38	**22**	16		3	88	66
G	3		7	3	**52**	3	6	74	22
W						**25**		25	0
N		1	1	1	3		**15**	21	6
TOTAL PLOTS	27	12	84	48	75	30	24		
OMISSION	13	6	62	26	23	5	9		

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Figure 5. Three photo interpreters working with the above image produced the cumulative results shown here. A total of 100 randomly distributed points of known identity were used in this interpretation test. The numbers in the body of the array of results indicate the total number of plots identified by all interpreters. The numbers in the bold-faced diagonal row of boxes indicate the number of plots identified correctly.

IMAGE 5: GROUND RESOLVABLE DISTANCE = 300-500 FEET

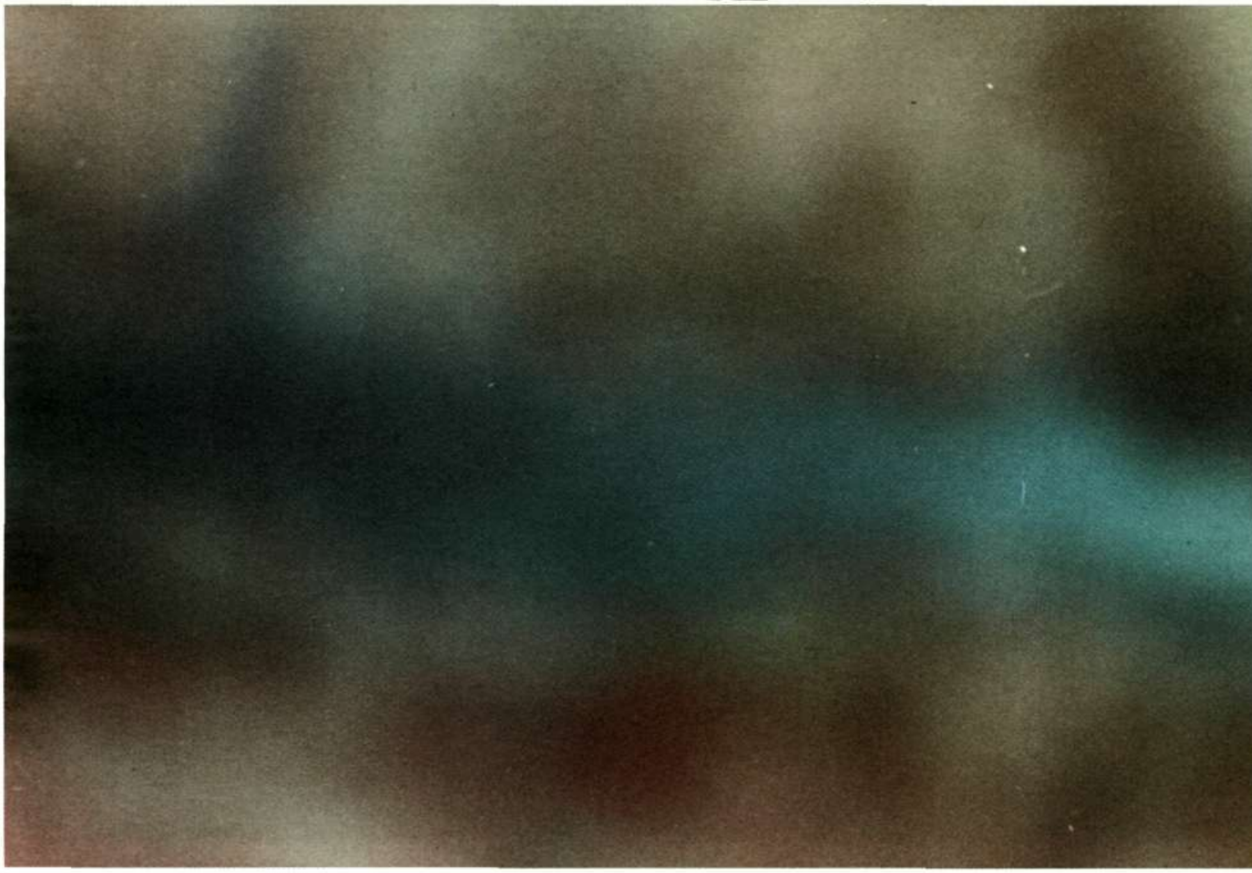


PHOTO INTERPRETER'S RESULTS	GROUND TRUTH: MP	E	MH	C	G	W	N	TOT. SEEN BY P.I.	COM. ERROR
MP	**9**	3	11	4	4			31	22
E	5	**8**	5	6				24	16
MH	2		**18**	15	6			41	23
C	2	1	34	**14**	23			74	60
G	2		14	6	**33**	3	11	69	36
W	2					**25**		27	2
N	5		2	3	9	2	**13**	34	21
TOTAL PLOTS	27	12	84	48	75	30	24		
OMISSION	18	4	66	34	42	5	11		

Figure 6. Three photo interpreters working with the above image produced the cumulative results shown here. A total of 100 randomly distributed points of known identity were used in this interpretation test. The numbers in the body of the array of results indicate the total number of plots identified by all interpreters. The numbers in the bold-faced diagonal row of boxes indicate the number of plots identified correctly.

1. G	21. C	41. G	61. G	81. G
2. MP	22. MP	42. W	62. N	82. G
3. C	23. G	43. MH	63. C	83. MH
4. MH	24. G	44. G	64. W	84. MH
5. MH	25. G.	45. G	65. W	85. C
6. MH	26. C	46. MH	66. W	86. G
7. C	27. N	47. C	67. N	87. C
8. C	28. W	48. C	68. W	88. MP
9. C	29. MP	49. C	69. MP	89. MH
10. G	30. MP	50. G	70. N	90. MH
11. G	31. MP	51. G	71. MP	91. G
12. G	32. MH	52. MH	72. G	92. MH
13. MH	33. E	53. G	73. E	93. MH
14. G	34. W	54. MH	74. G	94. MH
15. G	35. MH	55. MH	75. W	95. C
16. G	36. C	56. MH	76. MH	96. G
17. MH	37. MH	57. MH	77. N	97. MH
18. MP	38. W	58. E	78. MH	98. C
19. G	39. N	59. E	79. MH	99. MH
20. W	40. N	60. C	80. N	100. MH

Figure 7. Ground truth key for overlay in Figure 2.

CATEGORY	IMAGE RESOLUTION (FEET)				
	5-10	50-100	100-200	200-300	300-500
<u>COMPOSITE</u> (all types)					
Percent Correct	90.3	70.0	63.0	52.7	40.0
Percent Commission	9.7	30.0	37.0	47.3	60.0
<u>MONTEREY PINE</u> (MP)					
Percent Correct	100.0	92.6	77.8	51.9	33.3
Percent Commission	3.6	49.0	41.7	64.1	71.0
<u>EUCALYPTUS</u> (E)					
Percent Correct	91.7	50.0	75.0	50.0	66.7
Percent Commission	0.0	0.0	25.0	58.8	66.7
<u>MIXED HARDWOODS</u> (MH)					
Percent Correct	91.7	63.1	46.4	26.2	21.4
Percent Commission	6.1	28.4	37.1	36.1	56.1
<u>CHAPARRAL</u> (C)					
Percent Correct	85.4	41.6	45.8	45.8	29.2
Percent Commission	30.5	62.3	67.1	75.0	81.1
<u>ANNUAL GRASSLAND</u> (G)					
Percent Correct	89.3	80.0	76.0	69.3	44.0
Percent Commission	4.3	7.6	22.8	29.7	52.8
<u>WATER BODIES</u> (W)					
Percent Correct	100.0	93.3	90.0	83.3	83.3
Percent Commission	0.0	9.7	6.9	0.0	7.4
<u>NON-VEGETATED AREAS</u> (N)					
Percent Correct	75.0	75.0	58.3	62.5	54.2
Percent Commission	10.0	16.7	30.0	28.6	61.8

Figure 8. Interpretation results for each category expressed as percent correct and percent commission error.

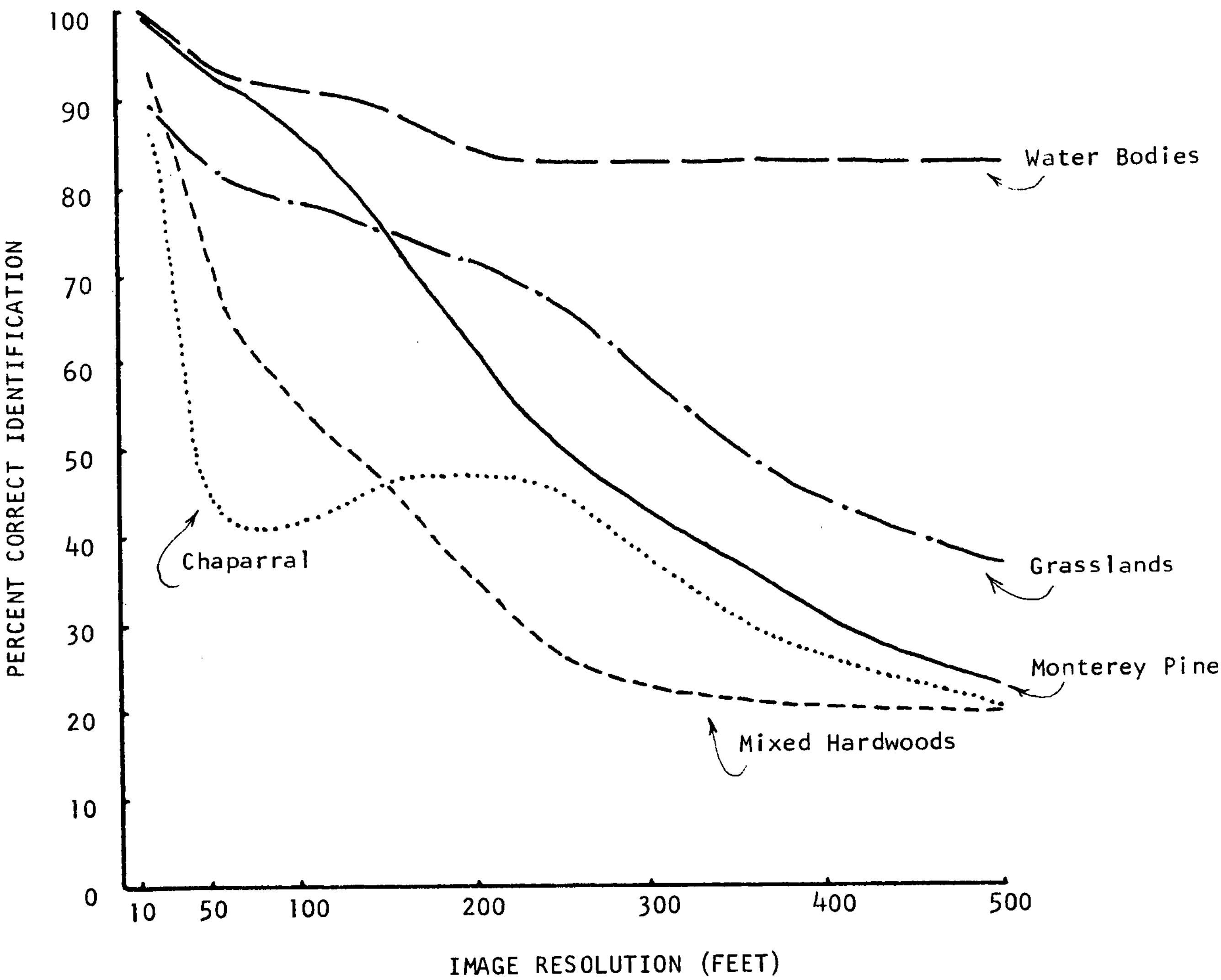


Figure 9. Interpretation results for all categories individually expressed as percent correct identification (data on eucalyptus and non-vegetated areas have been omitted due to an insufficient number of sample plots.)

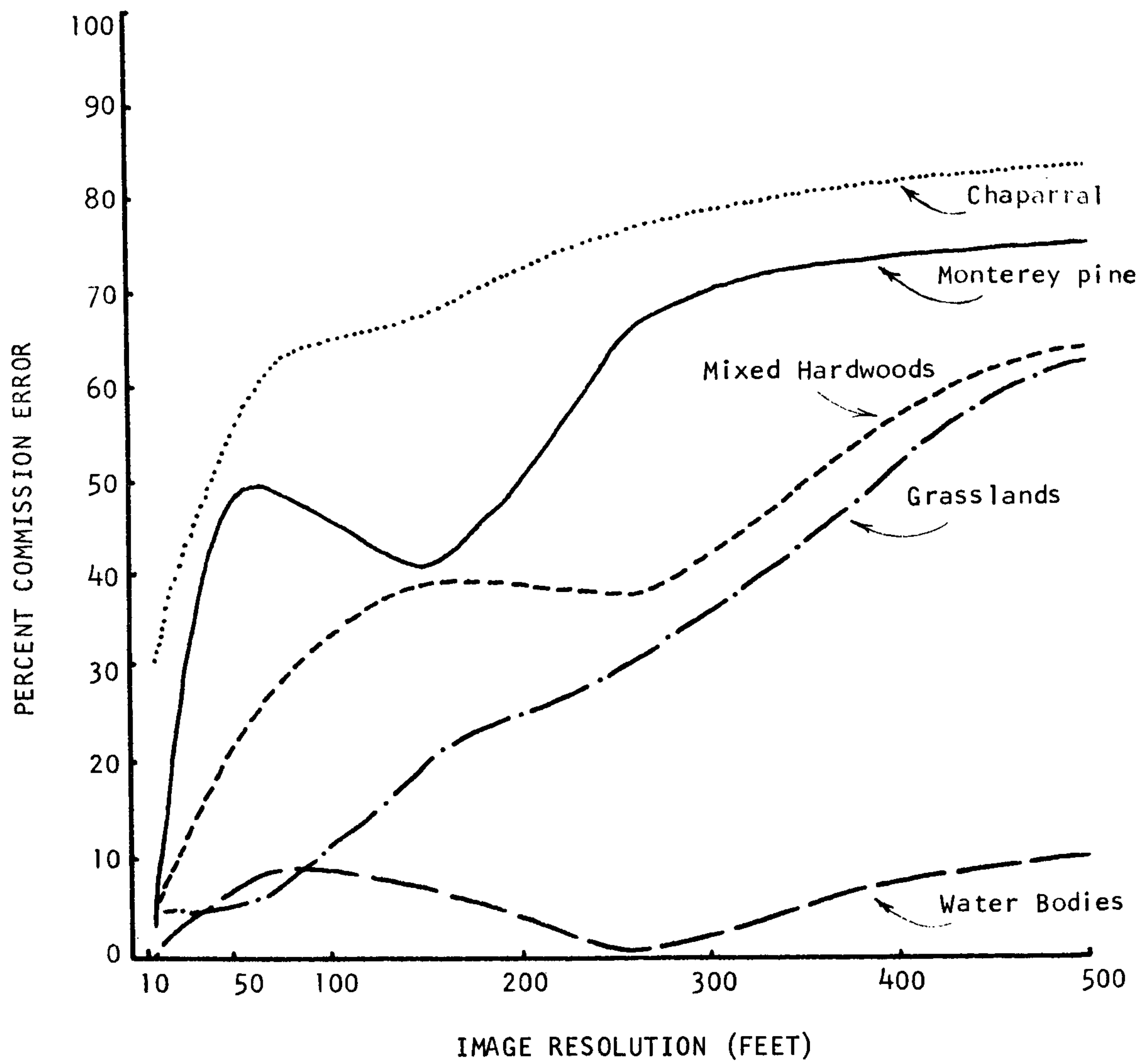


Figure 10. Interpretation results for all categories individually expressed as percent commission errors (data on eucalyptus and non-vegetated areas have been omitted due to an insufficient number of sample plots.)

CATEGORY	IMAGE RESOLUTION (FEET)				
	5-10	50-100	100-200	200-300	300-500
WOODY VEGETATION (MP, E, MH and C)					
Percent Correct	98.8	98.2	93.6	91.2	80.11
Percent Commission	4.4	7.7	9.6	13.9	19.4
GRASSLAND (G)					
Percent Correct	89.3	80.0	76.0	69.3	44.0
Percent Commission	4.3	7.7	23.0	29.7	52.2
WATER BODIES (W)					
Percent Correct	100.0	93.3	90.0	83.3	83.3
Percent Commission	0.0	9.7	6.9	0.0	7.4

Figure 11. Interpretation results for combined categories, expressed as percent correct and percent commission error.

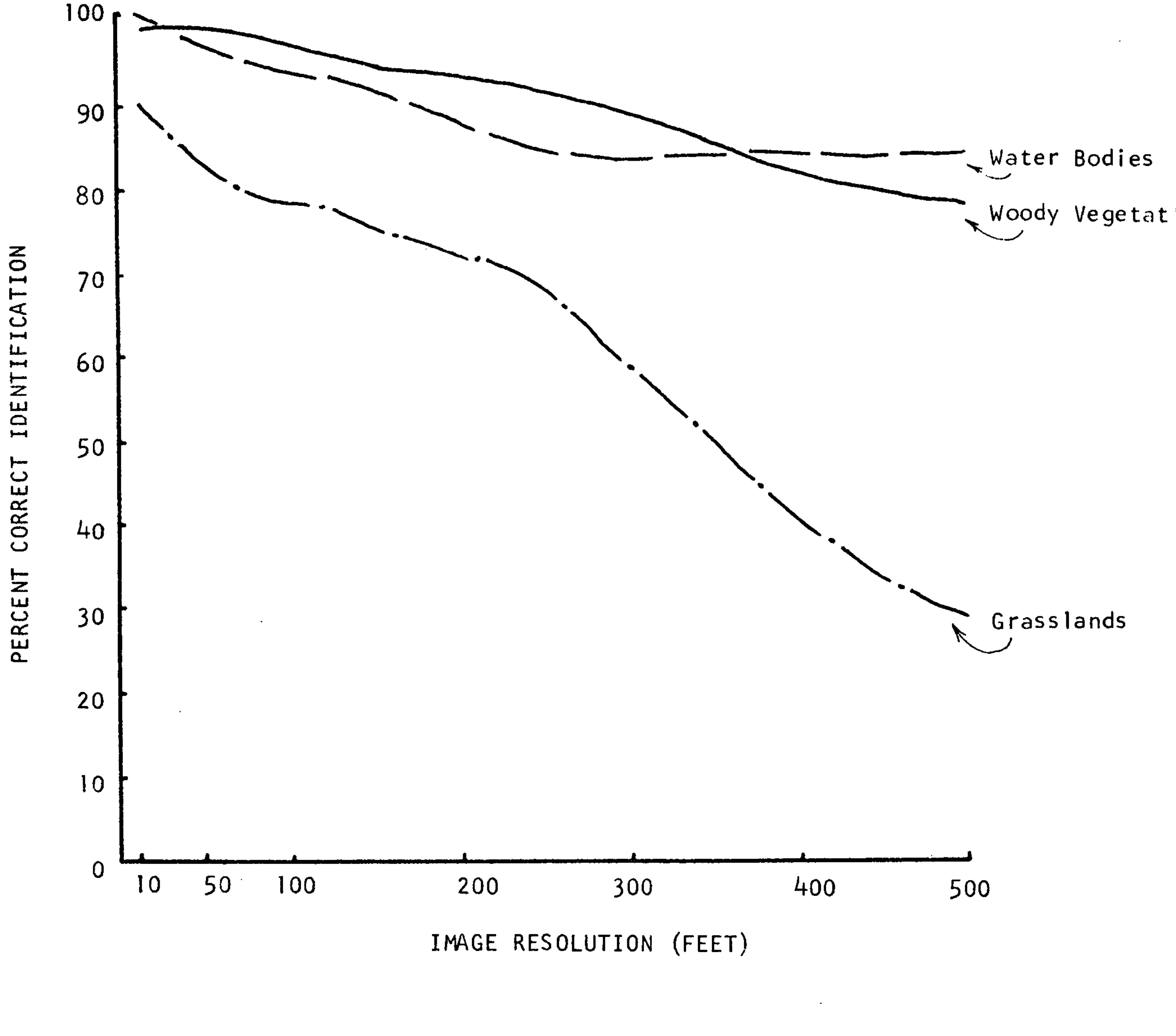


Figure 12. Interpretation results for woody vegetation, grasslands and water, expressed as percent correct identification.

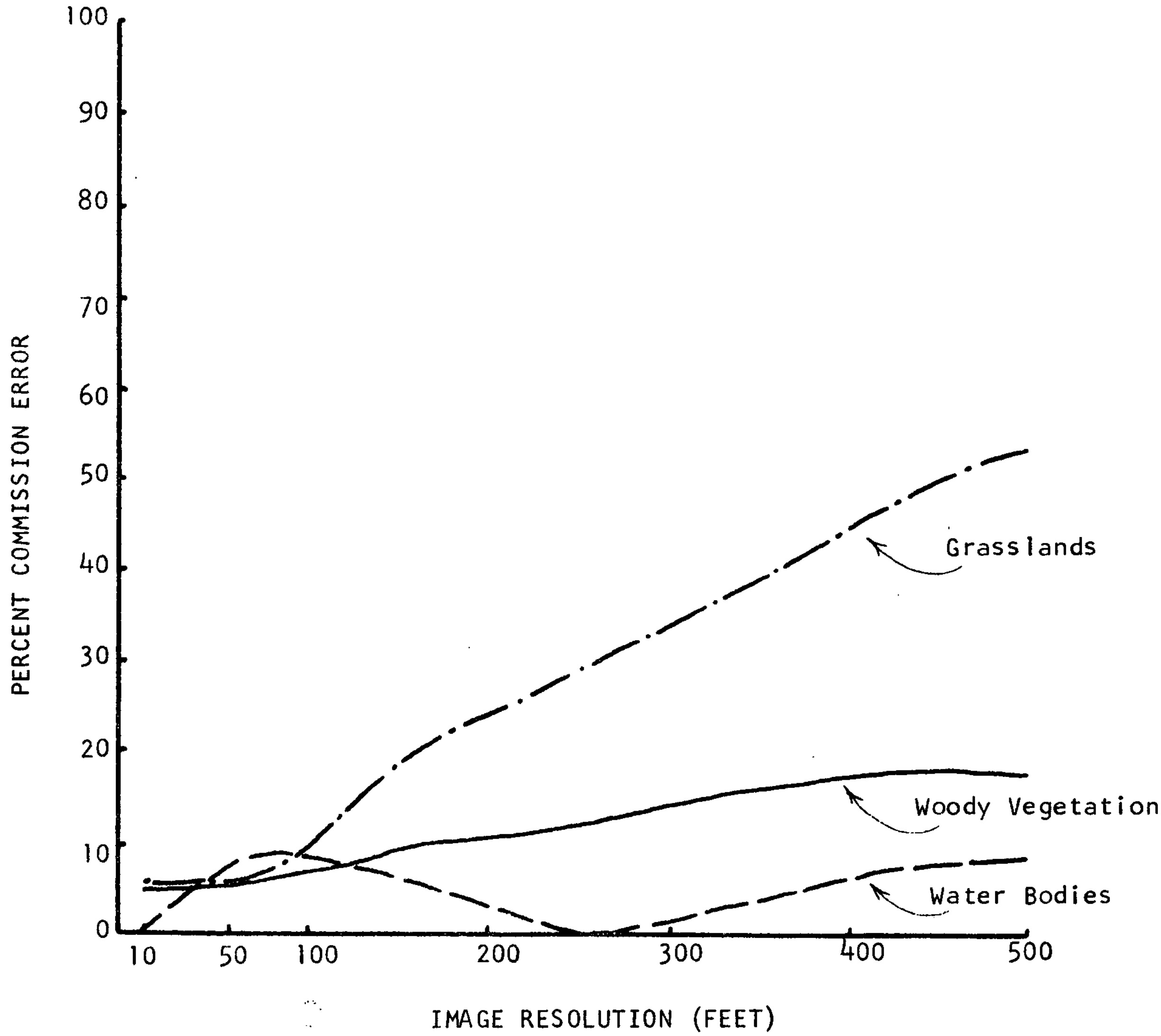
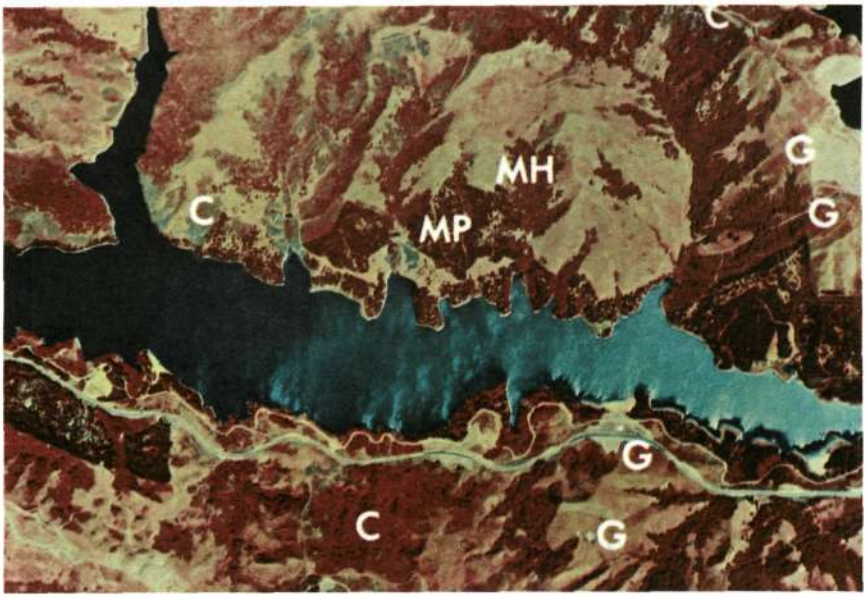
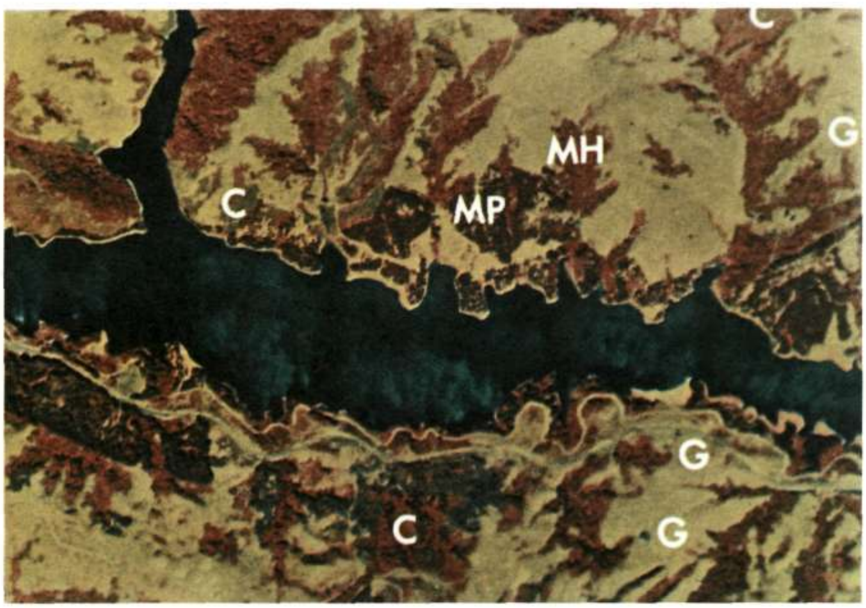


Figure 13. Interpretation results for woody vegetation, grassland and water, expressed as percent commission error.



Film: Ekta Aero Infrared
Aircraft: NASA Convair 240
Date: June 1, 1968



Film: Ekta Aero Infrared
Aircraft: NASA RB57F
Date: July 17, 1969

Figure 14. The accurate timing of image procurement greatly influences the interpretability of the resulting imagery. This example shows that in early June the phenological growth stages of annual grasslands in California are such that this cover type is often confused with adjacent woody vegetation. However, later in the year, the grasses have matured and dried and as a result the reflectance characteristics of grassland are quite different than those of hardwood vegetation. Consequently, the interpretation results reported here differentiating grasslands from other types might have been greatly improved if the analysis had been done on July imagery. (Annotations are explained in the text.)